§16. Current of Antenna Elements in Combline Antenna

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The currents at the Nth antenna element of the combline antenna can be expressed in the following equation using a 4x4 matrix A, the current at 1st antenna element I_1, I_N at N_{th} antenna element, and I_Z at the RF power supply;

$$A(I_{e1}\ \ I_{o1}\ \ I_{eN}\ \ I_{oN})^t = (-i\omega L_1 I_z\ \ -i\omega(L_1+2L_c)I_z\ \ -i\omega M_z I_z\ \ -i\omega M_z I_z)^t$$

where

$$u^{(2)} = \begin{pmatrix} -\dfrac{2t - i\omega L_a s}{2i\omega M_{ee}} & -\dfrac{i\omega L_a s}{2i\omega M_{ee}} \\ -\dfrac{i\omega(2L_c + L_a)s}{2i\omega M_{oo}} & -\dfrac{(2t + 4i\omega L_c) - i\omega(2L_c + L_a)s}{2i\omega M_{oo}} \end{pmatrix}$$

$$u^{(N-1)} = \begin{pmatrix} d_{11}^{(e)}u_{11}^{(3)} + d_{12}^{(e)}u_{11}^{(2)} & d_{11}^{(e)}u_{12}^{(3)} + d_{12}^{(e)}u_{12}^{(2)} \\ d_{11}^{(o)}u_{21}^{(3)} + d_{12}^{(o)}u_{21}^{(2)} & d_{11}^{(o)}u_{22}^{(3)} + d_{12}^{(o)}u_{22}^{(2)} \end{pmatrix}$$

$$u^{(N-2)} = \begin{pmatrix} d_{21}^{(e)}u_{11}^{(3)} + d_{22}^{(e)}u_{11}^{(2)} & d_{21}^{(e)}u_{12}^{(3)} + d_{22}^{(e)}u_{12}^{(2)} \\ d_{21}^{(o)}u_{21}^{(3)} + d_{22}^{(o)}u_{21}^{(2)} & d_{21}^{(o)}u_{22}^{(3)} + d_{22}^{(o)}u_{22}^{(2)} \end{pmatrix}$$

$$s = -\frac{R + i\omega L_b + \dfrac{1}{i\omega C}}{Z_A}$$

The input impedance Z is expressed as

$$ZI_Z + (R + i\omega L_2 + \frac{1}{i\omega C})(I_{e,N} + I_{o,N}) = 0$$

An actual LHD combline antenna has ten elements; the characteristics of the combline antenna is examined in the case of N=10 and in an adequate case; $L=9\times10^{-8}$[H], $L_a=L_b=4.5\times10^{-8}$[H], $L_c=M_{ee}=M_{oo}=9\times10^{-9}$ [H], $C=50\times10^{-12}$[F], $R=0.5[\Omega]$.

In Fig.1, real part and imaginary part of Z are shown by ω/ω_0. ω_0 is a resonant frequency of the even mode of the antenna element; $\omega_0/2\pi=75$[MHz]

The real part of the impedance becomes to zero at the $\Delta\omega/\omega_0\sim\pm0.1$; the region between $0.85<\omega/\omega_0<1.2$ is called a pass-band. We can inject a RF power to the combline antenna and drive a traveling wave to the plasma within this bandwidth. For example, as R increases, the width of pass-band becomes wider. When the resonant frequency is constant at $\omega_e=1/\sqrt{LC}$, the bandwidth becomes wider with the increase in C. It can be also changed by the distance between elements, how to feed the RF power, a configuration of the Faraday shields, and so on[1].

A resonant frequency $\omega_e/2\pi$ is selected at 75MHz; however taking into account a mutual inductance, a good condition where the even mode becomes dominant over the odd mode is obtained at the a little higher frequency than 75MHz. In Fig.2, the current characteristics of each antenna element in the case of the frequency, i.e. 76MHz is shown. As the value of R increases, the difference between the adjacent antenna elements becomes smaller and the decay length of the current becomes shorter.

Now we have made a mock-up antenna to compare the experiment with the calculated results. We are going to examine RF characteristics of the combline antenna in detail.

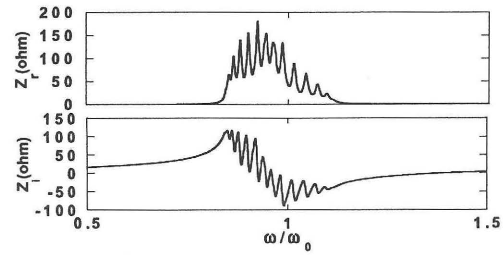

Fig.1 Characteristics of the impedance on the applied frequency

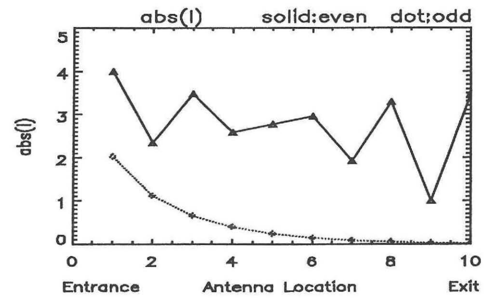

Fig.2 Current characteristics of each antenna element at f= 76MHz

Reference

[1] Takase, Y. et al. : TCM-Steady state Oparation, Kyushu (1999).

$$A = \begin{pmatrix} 2i\omega M_{ee}u_{11}^{(N-1)} & 2i\omega M_{ee}u_{12}^{(N-1)} & 2t & 0 \\ 2i\omega M_{oo}u_{21}^{(N-1)} & 2i\omega M_{oo}u_{22}^{(N-1)} & 0 & 2t + 4i\omega L_c \\ 2tu_{11}^{(N-1)} + 2i\omega M_{ee}u_{11}^{(N-2)} & 2tu_{12}^{(N-1)} + 2i\omega M_{ee}u_{12}^{(N-2)} & 2i\omega M_{ee} & 0 \\ (2t + 4i\omega L_c)u_{21}^{(N-1)} + 2i\omega M_{oo}u_{21}^{(N-2)} & (2t + 4i\omega L_c)u_{22}^{(N-1)} + 2i\omega M_{oo}u_{22}^{(N-2)} & 0 & 2i\omega M_{oo} \end{pmatrix}$$

$$u^{(3)} = \begin{pmatrix} -\dfrac{t}{i\omega M_{ee}}u_{11}^{(2)} - \dfrac{2i\omega M_{ee} - i\omega M_A s}{2i\omega M_{ee}} & -\dfrac{t}{i\omega M_{ee}}u_{12}^{(2)} - \dfrac{i\omega M_A s}{2i\omega M_{ee}} \\ -\dfrac{t + 2i\omega L_c}{i\omega M_{oo}}u_{21}^{(2)} - \dfrac{i\omega M_A s}{2i\omega M_{oo}} & -\dfrac{t + 2i\omega L_c}{i\omega M_{oo}}u_{22}^{(2)} - \dfrac{2i\omega M_{oo} - i\omega M_A s}{2i\omega M_{oo}} \end{pmatrix}$$